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Energizing the thermophysical properties of phase change material using carbon-based nano additives for sustainable thermal energy storage application in photovoltaic thermal systems

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ABSTRACT

As solar energy are intermittent in nature and not predictable, researchers and scientists are actively developing efficient thermal energy storage (TES) systems intending to maximize the utilization of solar energy. Phase change materials (PCM) are potential materials that are largely accessed towards TES. However, the notable drawback of PCM is their lower thermal conductivity, leading to slower heat transfer rates and reduced thermal energy storage density. Thus, the current study focuses on developing and exploring a PCM composite by embedding paraffin wax and graphene to enhance the heat transfer mechanisms, making it a promising option for TES applications. Various aspects of the composite's performance were examined, including its microstructural behaviour, chemical stability, thermal stability, thermal conductivity, thermal reliability, and heat transfer characteristics. The findings revealed that the inclusion of graphene led to a substantial increase of up to 75.09 % in thermal conductivity while preserving the melting enthalpy of the material. The newly developed nanocomposite also demonstrated chemically and thermally stable up to a temperature of 210 °C, and the thermal stability was slightly enhanced by adding nanoparticles. This nanocomposite also exhibited improved optical absorptance and reduced transmittance, enhancing its potential for solar energy absorption. It further demonstrated durability, maintaining stability even after undergoing 500 thermal cycles. Notably, the overall efficiency of the nano-enhanced PCM integrated photovoltaic-thermal system (PVT) enhanced by 29 % and 49 % greater than the PVT system and conventional PV system. Given these exceptional characteristics and performance enhancements, this nanocomposite material holds promise for significantly advancing future sustainable TES technologies.

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